Beam Dynamics in Circular Accelerators

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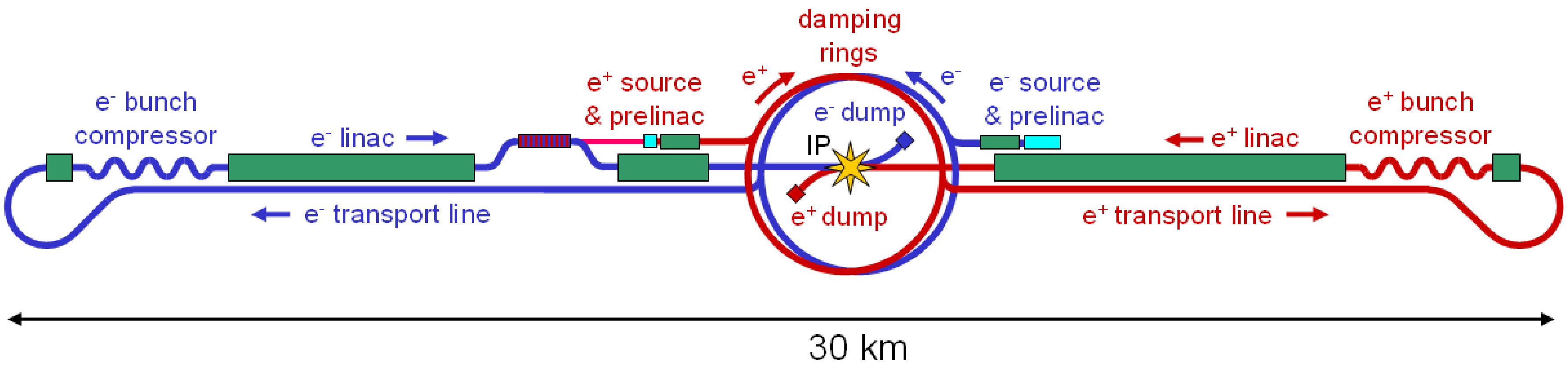
Overview

1. Recent work
   - Linear collider damping ring
   - Disturbance caused by injection

2. Current work
   - EMMA and Cancer therapy

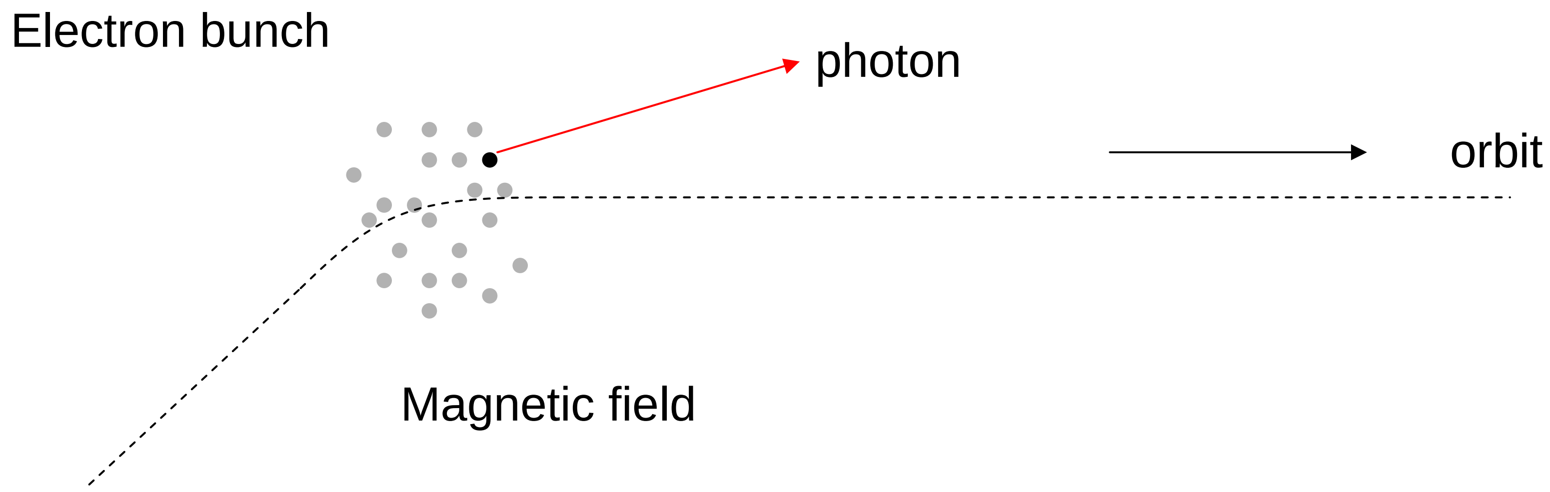
3. Future plans

Linear collider damping ring



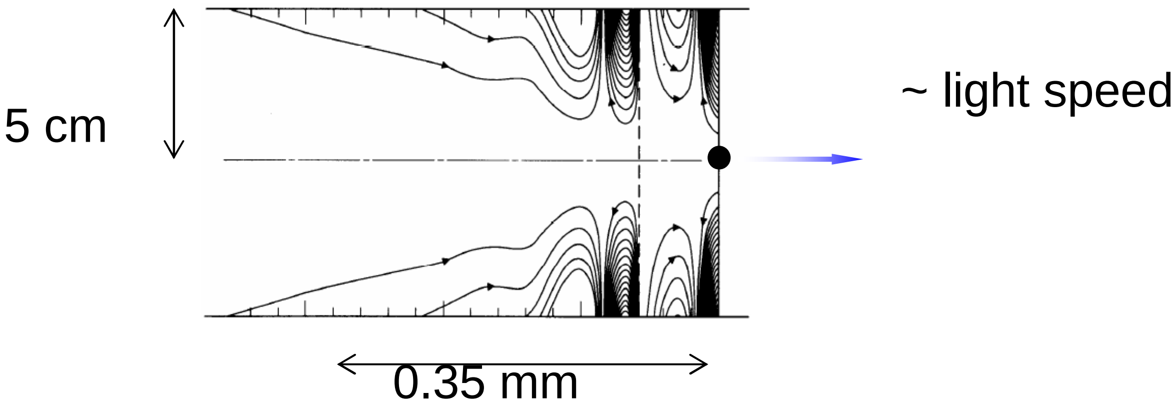
1. The linear collider accelerates a beam of electrons and a beam of positrons to an energy of 500 GeV, and allow them to collide.
2. Before each beam is accelerated, the vertical beam size must be reduced to less than 1 mm.
3. This is achieved using a damping ring.

Damping in the ring



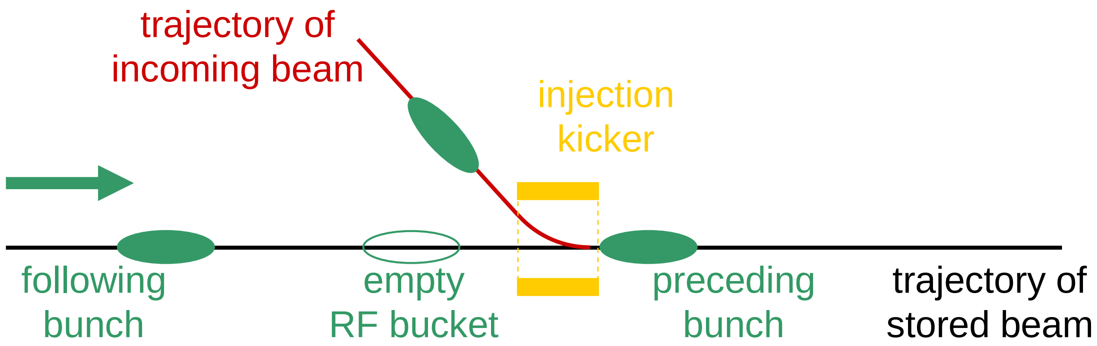
1. An electron is forced to stay on a definite orbit by a series of magnets along the ring.
2. The beam width arises because the electrons could oscillate about this orbit after injection.
3. Damping of this oscillation happens when the electron emits photons and loses energy.

Wake fields



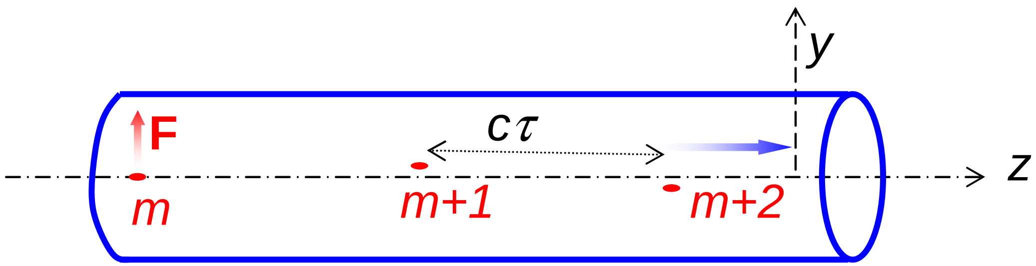
1. When electric field from an electron interacts with the surrounding walls of the vacuum, it induces image charges.
2. Since the electron travels close to light speed, the resultant electric field is behind the electron. Hence the name wake field.
3. This wake field disturbs the electrons trailing behind.

Transient effects



1. When a bunch of electrons is injected into the ring, it may not fall perfectly onto the orbit.
2. The resulting wake field produces a transverse force on the bunches already in the ring.
3. This disturbs the stable bunches and increases the beam size.

My calculations

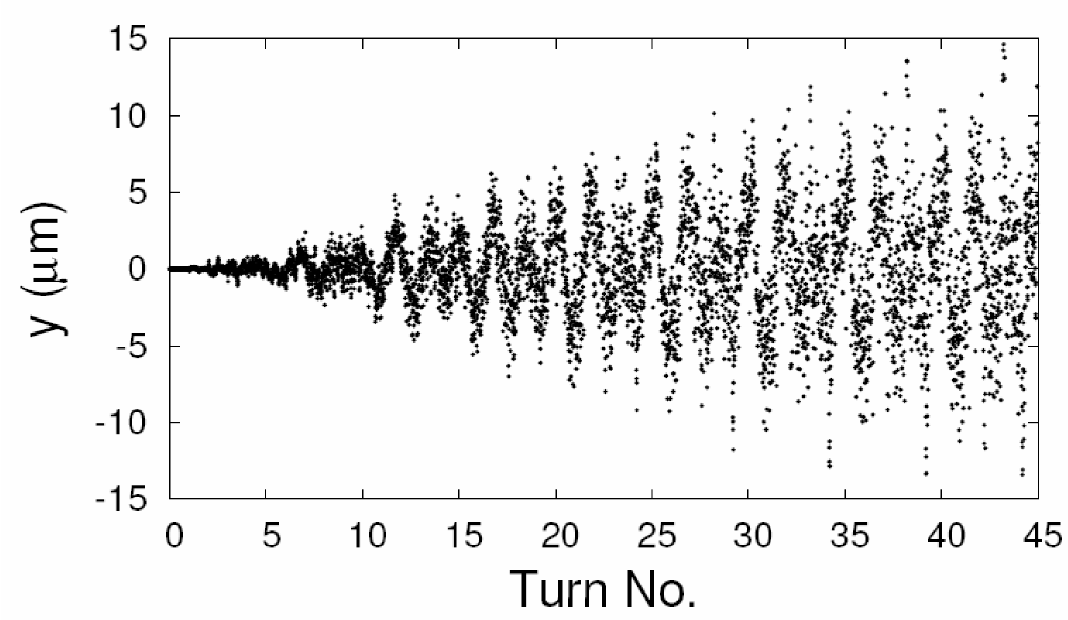


1. My research is to find ways to estimate the size of the beam as a result of the injection.

2. There are up to 5000 bunches. The effect of the wake field from each bunch travel round the ring many times.

3. The wake field is derived from Maxwell's equations, and the motion of each bunch is calculated using Newton's second law.

Extraction Jitter



1. As fresh bunches are injected, stable bunches are disturbed by the wake fields.

2. The above figures shows the displacement of the “stable” bunches just before extraction.

3. This jitter may be large enough for the electron and positron beams to miss each other when they eventually collide.

My contribution

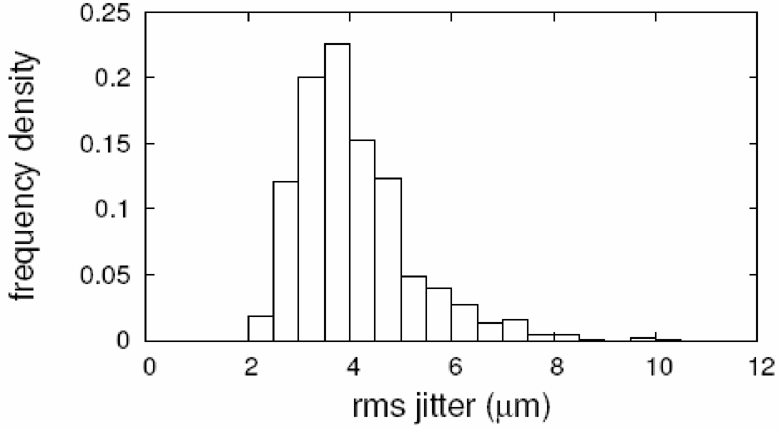


FIG. 7: Distribution of rms extraction jitter, for 1000 seeds of random injection jitter.

Took 1 day to calculate on my PC

1. There is a standard method to calculate the oscillations caused by the wake fields. It assumes that the magnetic fields are averaged out, and that no bunch is injected or extracted.

2. The damping ring has many separate magnets. My calculations take this into account. It shows that as a result, the oscillations are significantly larger. (Published in Physical Review Special Topics 2007).

3. I have developed an analytic method that speeds up the computation by 100,000 times. Jitter statistics can now be obtained quickly.

The Cockcroft Institute of Accelerator Science and Technology

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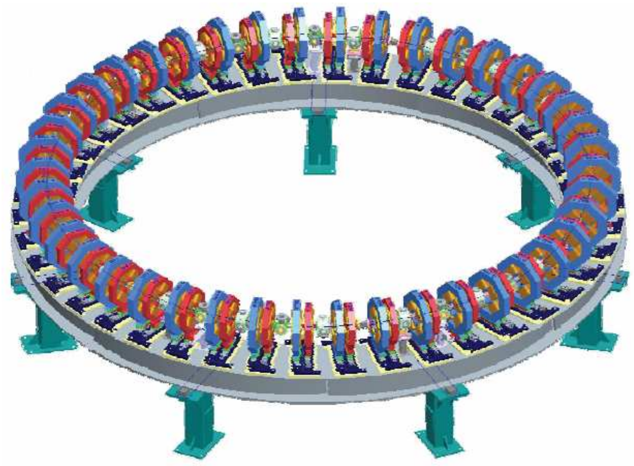
EMMA and Cancer therapy

To develop the methods to accelerate particles in a nonscaling FFAG accelerator:

1. To carry out simulation for the proton beam that would be used for cancer treatment.
2. To develop methods to control the complex beam behaviours.
3. To test these on a prototype , called EMMA, which uses electrons.



EMMA, Daresbury

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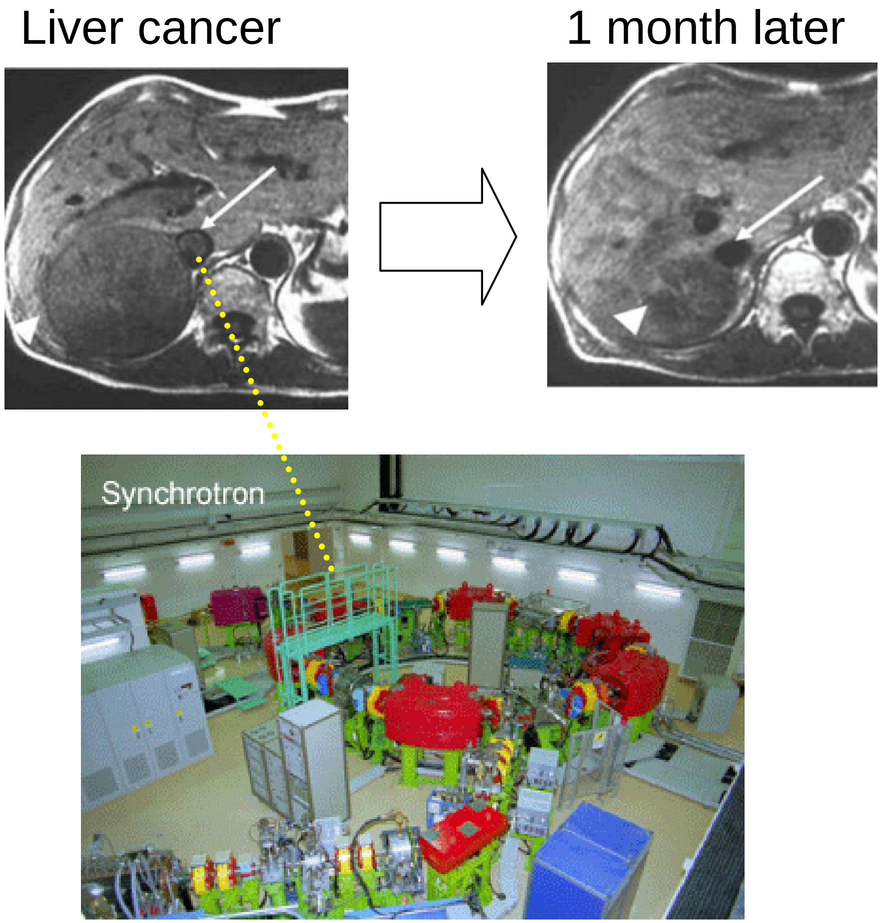
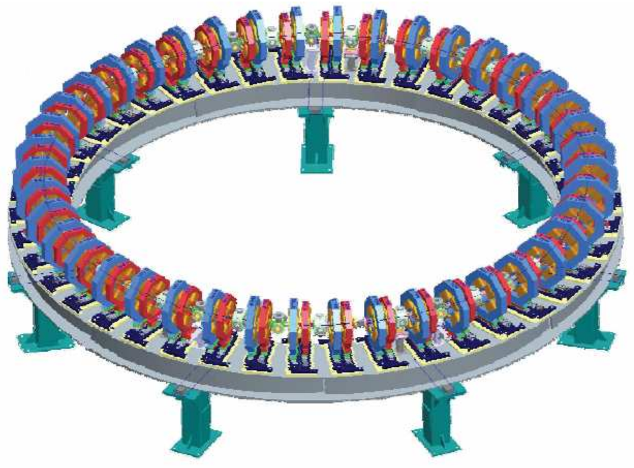
Cancer therapy with particles



Tsukuba University, Japan

The Nonscaling FFAG

This type of accelerator has a fixed magnetic field. It is expected to be smaller and cheaper than existing alternatives.



EMMA, Daresbury

1. This has smaller magnets than a cyclotron, and can accelerate much faster than a synchrotron.
2. But the beam can become unstable more easily when accelerated.
3. As revolution time decreases, particles would not synchronise with the accelerating cavities.
4. We have to develop new methods to control the beam.

Future plan

To fully develop the potential applications of the nonscaling FFGA :

1. **Medicine**. Energy can be changed easy. So the beam could target cancer cells in different parts of the body. Also cheaper.
2. **Energy**. High beam current is possible. This could be used in subcritical reactors to produce safe, clean nuclear power.
3. **Science**. The rapid acceleration could be appropriate for short lived particles, such as muons.